PODISUS MACULIVENTRIS (HEMIPTERA: PENTATOMIDAE) PREDATION ON LADYBIRD BEETLES (COLEOPTERA: COCCINELLIDAE)

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ABSTRACT

Adult *Podisus maculiventris* (Say) consumed no adult ladybird beetles (*Harmonia axyridis* Pallas) and 30-35% of larval ladybird beetles in no-choice laboratory trials. Nymphal *P. maculiventris* appeared to be more agile than adults in petri dishes and attacked 65% of both larval and adult *H. axyrides*; however, they only killed and consumed 50% of larvae and 20% of adult ladybird beetles. Ladybird beetle larvae were aggressive and often escaped, whereas adult beetles were usually rejected by the nymphal predators, suggesting unpalatability. Overall, *P. maculiventris* took more than four times longer to capture ladybeetle larvae than to capture fall armyworms (*Spodoptera frugiperda* [J. E. Smith]). In nature, while some ladybird beetles are undoubtedly consumed by *P. maculiventris*, most probably escape predation, either by evasion or through lack of palatability.

Key Words: *Harmonia axyrides*, prey selection, defense, palatability, refugia, no-choice tests.

RESUMEN

Los adultos de *Podisus maculiventris* (Say) no consumieron adultos del coccinélido *Harmonia axyridis* Pallas y sólo depredaron el 30-35% de sus larvas en ensayos de alimentación obligada. Las ninfas de *P. maculiventris* parecieron ser más ágiles que los adultos en las placas de petri y atacaron el 65% de las larvas y adultos de *H. axyridis*; sin embargo, estas sólo mataron y consumieron el 50% de las larvas y el 20% de los adultos del coccinélido. Las larvas del coccinélido fueron agresivas y a menudo escaparon, mientras que los adultos usualmente eran rechazados por las ninfas predatoras, lo cual sugiere su impalatabilidad. En general, *P. maculiventris* necesitó 4 veces más tiempo para capturar un coccinélido que para capturar un gusano trozador (*Spodoptera frugiperda* (J. E. Smith)). En la naturaleza, mientras algunos coccinélidos son sin duda consumidos por *P. maculiventris*, la mayoría probablemente escape a la depredación, ya sea por evasión o por falta de palatabilidad.

The predaceous hemipteran, *Podisus maculiventris* (Say), has a broad host range, consisting primarily of soft-bodied, slow-moving larvae of Coleoptera and Lepidoptera (Esselbaugh 1948, Mukerji & LeRoux 1965). Among those listed as prey species, however, are at least four species of predaceous Coccinellidae (McPherson 1980). These would seem to be unlikely prey for *P. maculiventris*, because of their typically agile, rapid movements and the variety of chemical defenses generally present in coccinellids (Dettner 1987).

Podisus maculiventris is a candidate for augmentative release (e.g., Hough-Goldstein 1996), but before large numbers are released, its potential impact on beneficial

arthropods should be evaluated. In this study, we examined the potential for *P. maculiventris* adults and nymphs to feed on larval and adult ladybird beetles.

Materials and Methods

Podisus maculiventris were provided initially by the Maryland Department of Agriculture (Plant Protection Section), Annapolis, MD; these were reared in our laboratory for one or two generations on fall armyworm, *Spodoptera frugiperda* (J. E. Smith), before use in trials. Fall armyworms were obtained from the DuPont Stine-Haskell Laboratory, Newark, DE, where they were reared on artificial diet. Colorado potato beetles, *Leptinotarsa decemlineata* (Say), were field-collected as adults, and larvae were reared on greenhouse-grown potatoes ('Superior'). Ladybird beetle (*Harmonia axyridis* Pallas) adults and larvae were collected from mixed, weedy vegetation on the University of Delaware Experiment Station Farm immediately before use.

Four no-choice trials were conducted between 11 and 25 July, 1995. No-choice experiments were used exclusively, because these are more likely to result in consumption and thus are a more stringent test of prey suitability than choice tests. Predators were fed in the colony 24 h prior to the start of each experiment. For each trial, *P. maculiventris* were placed individually in plastic petri dishes approximately 2 h before the trial began. Between 8 and 20 (usually 10) dishes were set up for each prey type, and one potential prey was placed in each dish. The dishes were observed continuously for 1 h after prey were introduced and then checked for prey consumption every half hour for the next 6 h. Dishes were left at room temperature (approximately 24°C) overnight and checked again for consumption 20 h after set-up.

Two trials were run using *P. maculiventris* adults and two using fourth instars. For each *P. maculiventris* life stage, half the trials used arenas consisting of 9 by 1.3 cm plastic petri dishes, and half used 11 by 2.5 cm plastic dishes containing a piece of 9-cm filter paper, folded in half with the edges folded up as a refugium.

The first trial compared fall armyworm larvae, Colorado potato beetle larvae, ladybird beetle larvae, and ladybird beetle adults as potential prey. Subsequent trials eliminated Colorado potato beetle, since both it and fall armyworm were palatable.

Results of encounters (consumption or no consumption) were evaluated using Fisher's Exact Test (SAS Institute 1990). Times to capture (in min) of different types of prey for those *P. maculiventris* that consumed prey during each 20-h trial were compared using Analysis of Variance (ANOVA; PROC GLM, SAS Institute 1990). Time of capture was assigned as soon as the predator inserted its proboscis firmly and securely into the prey without either the prey escaping or the predator rejecting the prey. Attacks that occurred between 1 h and 6 h were assigned times as soon as they were observed (e.g., a capture noted at 1.5 h was assigned 90 min, even though it may have occurred somewhat sooner). Attacks that occurred overnight were (conservatively) assigned a time of 7 h (420 min), even though they may actually have occurred somewhat earlier or considerably later. Time of capture over all trials for all predators that consumed fall armyworms or ladybird beetle larvae was also analyzed by predator stage (adult or fourth instar), type of arena (9-cm or 11-cm with refugium) and prey type (fall armyworm or ladybird beetle larva), using ANOVA (SAS Institute 1990).

Results

In small dishes without refugia, *P. maculiventris* adults ate 100% of the fall armyworms and Colorado potato beetle larvae, 35% of the ladybird beetle larvae, and none of the ladybird beetle adults (Table 1). Consumption was similar in the larger dishes

with refugia where adult *P. maculiventris* ate 100% of the fall armyworms, 30% of the ladybird beetle larvae, and none of the ladybird beetle adults. In both trials, consumption rate varied significantly by prey ($P<0.0001$, Fisher's Exact Test). The time to capture was significantly shorter for fall armyworms than for ladybird beetle larvae in the 11-cm arenas ($F = 17.27$, df = 1, $P = 0.0010$; ANOVA, Table 1). A similar trend was observed in the 9-cm dishes ($F = 3.27$, df = 2, $P = 0.0581$, Table 1).

In 9-cm and 11-cm dishes, respectively, *P. maculiventris* fourth instars killed and consumed 60 and 80% of the fall armyworms, 30 and 70% of the ladybird beetle larvae, and 10 and 30% of the ladybird beetle adults during the 20-h observation period (Table 1). Differences in nymphal consumption by prey type were not significant for the 9-cm dish test ($P = 0.080$) or the 11-cm dish test ($P = 0.111$); however, the difference was significant for the two nymph tests considered together ($P = 0.007$, Fisher's Exact Test). The time to capture (for those that consumed prey) did not differ significantly by prey type for nymphs in 9-cm dishes (ANOVA, $F = 0.32$, $P = 0.5883$, df = 1), but approached significance in 11-cm dishes ($F = 3.36$, $P = 0.0624$, df = 2) with fall armyworms on average captured more quickly than ladybird beetle larvae or adults (Table 1).

In addition to ladybird beetles that were killed and consumed by *P. maculiventris* nymphs, several other ladybird beetle larvae (2 in the 9-cm arena and 1 in the 11-cm arena) and nearly half of the ladybird beetle adults (4 in the 9-cm arena and 5 in the 11-cm arena) were attacked and apparently sucked by the *P. maculiventris* nymphs for one or more brief periods, and then abandoned. Thus, the nymphs actually caught and "sampled" 65% of the ladybird beetle larvae and 65% of the ladybird beetle adults (over both dish sizes), but only consumed and killed 50% of the larvae and 20% of the adult ladybird beetles. Ladybird beetle larvae often attempted to bite the predator's

TABLE 1. CONSUMPTION AND TIME TO CAPTURE OF DIFFERENT PREY BY *PODISUS MACULIVENTRIS*.

Predator Stage	Arena	Prey[1]	No. Consumed (N)	Time (min.) to Capture (mean ± SEM)
Adult	9-cm	FAW	8 (8)	48 ± 23
		CPB	9 (9)	144 ± 54
		LBBL	7 (20)	253 ± 79
		LBBA	0 (10)	—
Adult	11-cm, refugia	FAW	10 (10)	84 ± 42
		LBBL	6 (20)	367 ± 53
		LBBA	0 (10)	—
Fourth instar	9-cm	FAW	6 (10)	23 ± 19
		LBBL	3 (10)	7 ± 4
		LBBA	1 (10)	—
Fourth instar	11-cm, refugia	FAW	8 (10)	77 ± 33
		LBBL	7 (10)	289 ± 70
		LBBA	3 (10)	146 ± 137

[1]FAW, fall armyworm; CPB, Colorado potato beetle; LBBL, ladybird beetle larva; LBBA, ladybird beetle adult.

proboscis and frequently escaped, whereas adult ladybird beetles were usually rejected by the predator.

Analysis of variance over all experiments on time of capture by predators that consumed fall armyworms or ladybird beetle larvae indicated a trend toward more rapid capture by *P. maculiventris* nymphs than by adults (Table 2). Prey were captured more rapidly in 9-cm dishes without refugia than in 11-cm dishes with refugia (Table 2); fall armyworms were captured much more quickly than ladybird beetle larvae (Table 2).

Discussion

Adult *P. maculiventris* appeared to be unable to capture ladybird beetle larvae or adults successfully because of their lack of agility (in small petri dishes) compared with the quick-moving prey. Those adult predators that did capture ladybird beetle larvae, however, did not subsequently reject them.

Podisus maculiventris nymphs appeared to be considerably more agile (in petri dishes) than *P. maculiventris* adults or, perhaps, they were simply more highly motivated to feed than the adult predators. Both ladybird beetle larvae and adults were caught by the predator nymphs. Once caught, however, nearly a quarter of the ladybird beetle larvae and 30% of the ladybird beetle adults either escaped or were rejected by the nymphs after one or more feeding bouts. Ladybird beetle larvae responded aggressively to predation attempts in a manner similar to that described by Marston et al. (1978) for corn earworm, *Heliothis [Helicoverpa] zea* (Boddie). Adult ladybird beetles did not respond aggressively to attack, and thus were apparently unpalatable to the predator. Some of the "sampled" ladybird beetle larvae or adults may have died eventually due to injection of salivary digestive enzymes (Cohen 1990, 1995), although we did not observe any obvious ill effects during several days in the laboratory.

TABLE 2. *PODISUS MACULIVENTRIS* TIME TO CAPTURE BY PREDATOR LIFE STAGE (ADULT OR NYMPH), TYPE OF ARENA (9-CM WITH NO REFUGIUM OR 11-CM WITH REFUGIUM), AND TYPE OF PREY (FALL ARMYWORM OR LADYBIRD BEETLE LARVA).

Variable	N	Time (min) to Capture (mean ± SE)	F[1]	*P*[1]
Predator Stage				
Adult	31	168 ± 33	2.65	0.1099
Fourth instar	24	116 ± 33		
Arena				
9-cm	24	97 ± 32	6.15	0.0165
11-cm, refugia	31	183 ± 33		
Prey[2]				
FAW	32	62 ± 17	28.63	0.0001
LBBL	23	262 ± 40		

[1]Overall F value = 12.25 (df=3, 51), *P* = 0.0001 (PROC GLM, SAS Institute 1990).
[2]FAW, fall armyworm; LBBL, ladybird beetle larva.

Over all trials, *P. maculiventris* took more than four times longer to capture ladybird beetle larvae than to capture fall armyworms, probably due to the agility and speed of the ladybird beetle larvae in evading the predators. Fall armyworms, in contrast, were slow-moving, with little defense evident against predation. Because the predators were reared on fall armyworms prior to the trials, however, it is also possible that some adaptation to this prey species may have occurred.

Arena size and presence of refugia primarily affected time to capture rather than total prey captured, with prey overall captured nearly twice as quickly in the smaller dishes that lacked refugia than in the larger dishes with refugia. The larger dishes with refugia undoubtedly reflect natural conditions somewhat better than the small empty dishes. However, even the larger dishes did not allow flight, an obvious means of escape for adult ladybird beetles in the field.

In summary, this species of ladybird beetle (*Harmonia axyrides*), which was by far the most abundant coccinellid species in our study area in July of 1995, was clearly not a preferred prey for *P. maculiventris*. Undoubtedly some ladybird beetles are eaten by the predator in nature; indeed, during specimen collection for these experiments, one *P. maculiventris* nymph was observed feeding on an *H. axyrides* larva. Under some circumstances, local losses of coccinellids due to *P. maculinventris* predation could be high. In general, however, most larvae and especially adults of this coccinellid species are likely to escape predation by most *P. maculiventris*. We predict that other predaceous coccinellids will show similar behavioral and chemical predation avoidance characteristics.

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